U. S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-6240 28 DEC 1962

GEOMAGNETIC FLUCTUATION STUDIES
AT THE
U. S. NAVAL AIR DEVELOPMENT CENTER

FOUNDATIONAL RESEARCH PHASE REPORT
WEPTASK NO. R360FR102/2021/R011-01-01
Task No. FR-30305

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Reported by: D. P. Miles   R. P. Lepping
Special Methods Division

Approved by: W. S. Lee, Superintendent
Special Methods Division

R. I. Mason
Technical Director

S U M M A R Y

A proton precession station magnetometer and a rubidium vapor station magnetometer have been in operation at the U. S. Naval Air Development Center for considerable periods since July 1961. Experience obtained concerning the operational reliability of these magnetometers when operated for sustained periods is discussed briefly. Examples are shown of rubidium vapor magnetometer recordings of a sudden commencement storm, a magnetic bay, micropulsations during a storm, and a micropulsation storm. Charts from the rubidium vapor magnetometer and an AN/ASQ-10 magnetic anomaly detector (MAD) system operating simultaneously on several occasions are shown. A separate channel containing a filter to duplicate the AN/ASQ-10 passband has been added to the rubidium vapor magnetometer, and several records of geomagnetic noise in this passband as recorded by this instrument are shown.

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INTRODUCTION

For more than a year, personnel at the U. S. Naval Air Development Center (NAVAIRDEVCEN) have been observing fluctuations in the earth's geomagnetic field at Johnsville, Pennsylvania, with a proton precession magnetometer[1] and a rubidium vapor magnetometer installed at a remote location at the Center. The purpose of this foundational research is to familiarize MAD development personnel with the performance of several new types of magnetometers, with the various forms of fluctuations exhibited by the geomagnetic field, and with the effect of these fluctuations on MAD system performance.

DESCRIPTION OF INSTRUMENTATION

The proton precession magnetometer is operated at a sensitivity of approximately 70 gammas (1 gamma = 10^{-5} oersteds) full scale and at a chart speed of 1/2 inch per hour. This magnetometer, whose sensor unit contains Hexane, serves mainly to give a picture of the general magnetic character of the field for a particular period, and because of the wide dynamic range of this equipment, for recording major magnetic "storms."

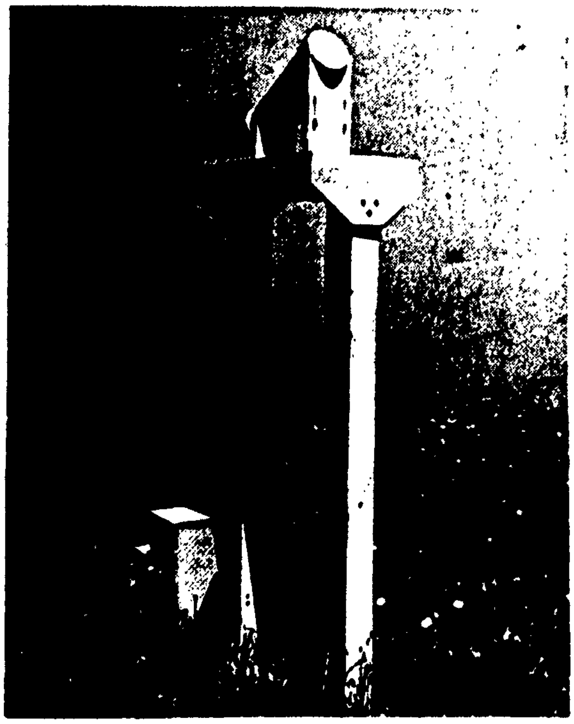

FIGURE 1 - Sensor Unit and Mounting Location for the Rubidium Vapor Magnetometer at NAVAIRDEVCEN

The rubidium vapor magnetometer provides a continuous recording of the geomagnetic field at full scale sensitivities of 20, 6.7, or 2 gammas at slow or fast chart speeds. The maximum sensitivity of 2 gammas full scale and the 2-inch-per-minute chart speed are used during special studies when an observer is present. For unattended operation, this magnetometer is operated at a sensitivity of 6.7 gammas full scale and a chart speed of 6 inches per hour.

Figure 1 shows the mounting location for the sensor of the rubidium vapor magnetometer. When in use, the sensor is covered with a thermally insulated box. This is necessary, in addition to the

1. *Report No. NADC-AW-6226, "Proton Precession Magnetometer as a Standard at the U. S. Naval Air Development Center," of 14 Sep 1962*

thermostatic control provided with the instrument, to permit operation throughout the wide range of temperatures encountered.

The sensing unit for the proton precession magnetometer is mounted on a single post in the same area as the sensing unit for the rubidium vapor magnetometer. In both installations the sensing units are at least 6 feet above the ground so that the effects of earth currents are minimized.

RESULTS AND DISCUSSION

MAGNETOMETERS

Electronic maintenance has been a problem in trying to obtain continuous operation with these magnetometers. False readings or "spikes" have created the principal problem with the proton precession magnetometer. Proper operation was obtained only after considerable modification to the electronic counter and relay damping circuits. Operational difficulties with the rubidium vapor magnetometer have occurred mainly with the life of the rubidium vapor spectral lamp, operating temperature requirements, and electronic failures.

GEOMAGNETIC STORMS

The magnetic storm is probably the best-known form of geomagnetic field variation wherein the strength and the direction of the earth's magnetic field are disturbed an appreciable amount, sometimes as much as 500 gammas and 2 degrees, respectively, and remain abnormal for several days[2]. Figure 2 shows a "sudden commencement" magnetic storm as recorded with the rubidium vapor magnetometer. This storm began at 0220 hours UT on 22 February 1962 with a sudden decrease of 10 gammas in the field. All storms do not begin with sudden changes as shown in the figure; about half start gradually.

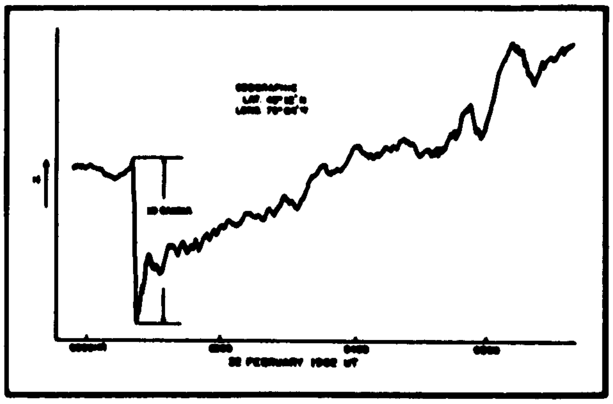

FIGURE 2 - A "Sudden Commencement" Magnetic Storm Recorded by the Rubidium Vapor Magnetometer at NAVAIRDEVCEN

2. Grover, F., S. J. and Hayden, F. J., S. J.; "A Survey of Geomagnetism"; Georgetown Observatory Monograph No. 16, AFCRL-TN-60-664; ASTIA No. AD-253574

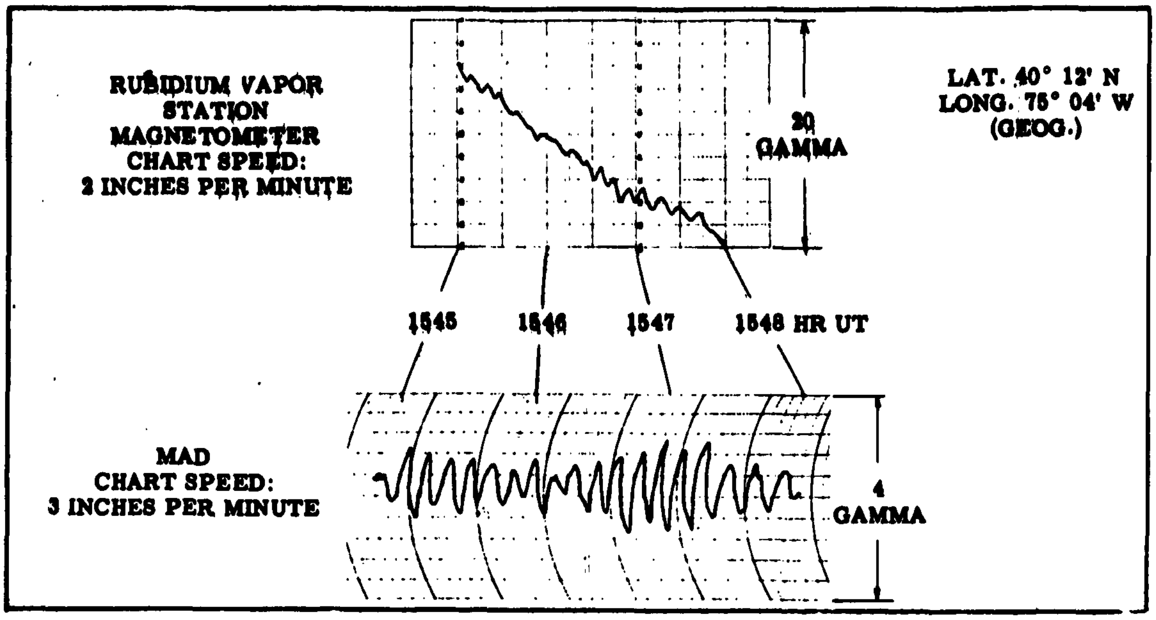

FIGURE 3 - Geomagnetic Fluctuations at NAVAIRDEVCEN, 13 July 1961, 1545 to 1548 Hours UT

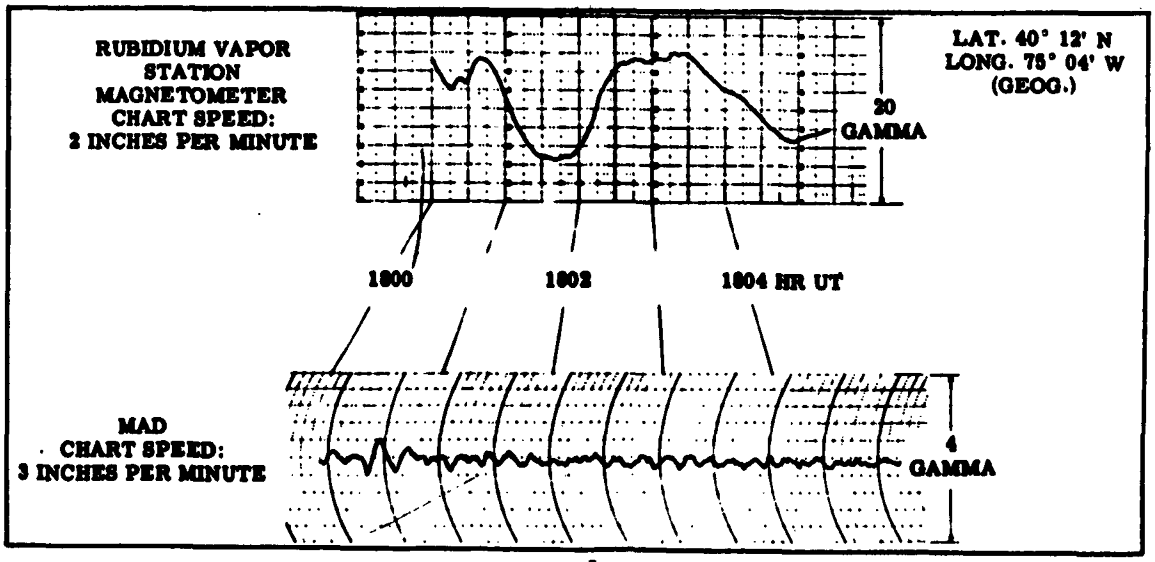

FIGURE 4 - Geomagnetic Fluctuations at NAVAIRDEVCEN, 13 July 1961, 1800 to 1804 Hours UT

Magnetic storms do not necessarily produce noise within the passband of the MAD equipment[3,4] for the duration of the storm, but are more apt to produce noise on an MAD equipment during a phase of the storm when the

3. NAVAIR 16-30ASQ10-502, "Handbook, Service Instructions; Magnetic Detecting Set AN/ASQ-10"

4. AN16-30ASQ8-3, "Handbook Maintenance Instructions; Detecting Set AN/ASQ-8"

rate of change of the field is within the passband. This is illustrated in figures 3 and 4.

Figure 3 shows the output of the rubidium vapor magnetometer operating at a sensitivity of 20 gammas full scale for a phase of a magnetic storm on 13 July 1961. Because of the storm, the field changed approximately 17 gammas in 3 minutes. Such a change would not produce appreciable noise on an MAD system. However, a cyclic variation having a period of about 10 seconds was superimposed on the main field change.

The effect of such variations on an MAD equipment is shown in the lower chart on figure 3. Although the chart speeds are different, correspondence is evident, for example, in the reduced activity near 1546 hours. While these signals would not be mistaken for submarine signals, they definitely reduce the range of detection during the period. They might well be misconstrued to be equipment noise, however, by fleet operating personnel lacking specific information as to their source. The result could be unnecessary aircraft "down-time" and equipment maintenance.

Figure 4 shows a similar trace from the rubidium vapor magnetometer later in the same storm. The variations are of similar magnitude to those in figure 3. However, the left portion of the trace on the MAD chart shows the effect of a particular single-cycle storm variation in the form of a single, submarine-like, signal distinct from the noise level of the trace.

GEOMAGNETIC FLUCTUATIONS

Geomagnetic variations also exist in forms other than outright storms. Figure 5 shows a magnetic "bay" preceded by a form of cyclic variations in the field. A bay is a simple form of field variation, departing from the normal value, reaching a peak, and returning to the normal value in a few hours. These bays start either with an increase or decrease in the field, and about half of them are preceded by the cyclic effect shown in figure 5.

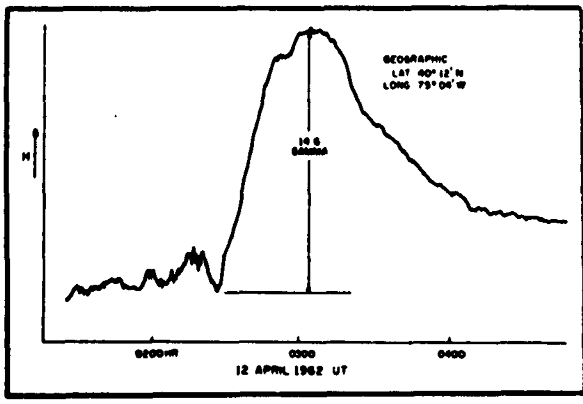

FIGURE 5 - Geomagnetic "Bay" Immediately Preceded by Cyclic Variations in the Field

Figure 6 shows the gradual commencement of a micropulsation storm, which is another form of geomagnetic fluctuation. The top trace was recorded with the rubidium vapor magnetometer set at a sensitivity of 6.7 gammas full scale and a chart speed of 6 inches

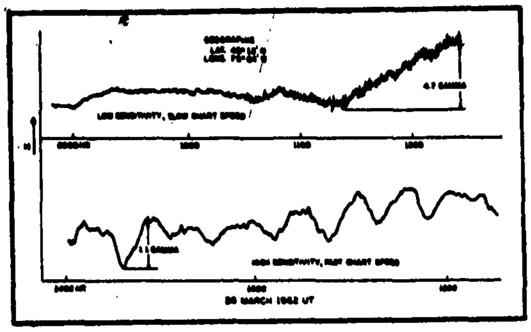

FIGURE 6 - A Micropulsation Storm Recorded at Slow and Fast Chart Speeds and Low and High Sensitivity Respectively by the Rubidium Vapor Magnetometer at NAVAIRDEVCEN

per hour. The storm started at about 0430 EST (0930 UT) before the beginning of the diurnal variation, and consisted of a generally continuous cyclic variation that usually persists for hours, although no magnetic storm in the usual sense is in progress. The lower trace shows the cyclic characteristic of the field recorded at a sensitivity of 2 gammas and a chart speed of 2 inches per minute.

Micropulsations are fluctuations having periods from less than a second to several (2 to 3) minutes, and amplitudes of 0.002 to 5 or 10 gammas[5]. By their nature, these fluctuations are of a form to affect MAD equipment, particularly when their frequencies are at or near the MAD passband. As the sensitivity of MAD is increased, this particular phenomenon may become more of a problem.

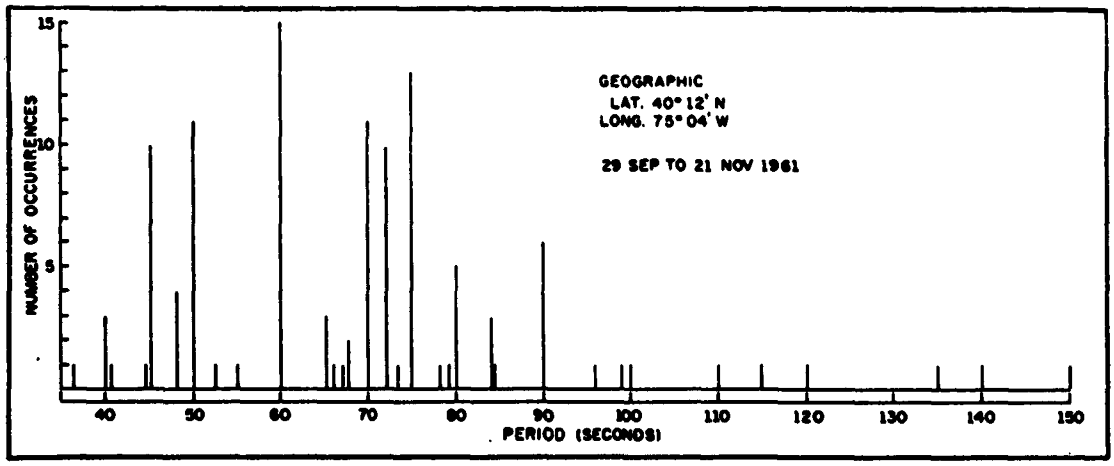

FIGURE 7 - Bar Graph Showing the Number of Occurrences of Micropulsations Versus Period for the Records Obtained Between 29 September and 21 November 1961

Figure 7 is a bar graph made from a preliminary analysis of rubidium vapor magnetometer records obtained between 29 September and 21 November 1961, with the equipment set at a sensitivity of 6.7 gammas full scale

5. *Benioff, H.; "Observations of Geomagnetic Fluctuations in the Period Range 0.3 to 120 seconds"; Jour Geophys Res Vol 65, No. 5, May 1960, pp 1413-1422*

and a chart speed of 6 inches per minute. Micropulsations of periods of 40 seconds or longer and of intensities of 0.1 gamma or greater were observed. Approximately 140 occurrences were observed during 53 days. The graph shows the number of occurrences versus the period of the micropulsations. The predominant periods lie between 45 and 75 seconds.

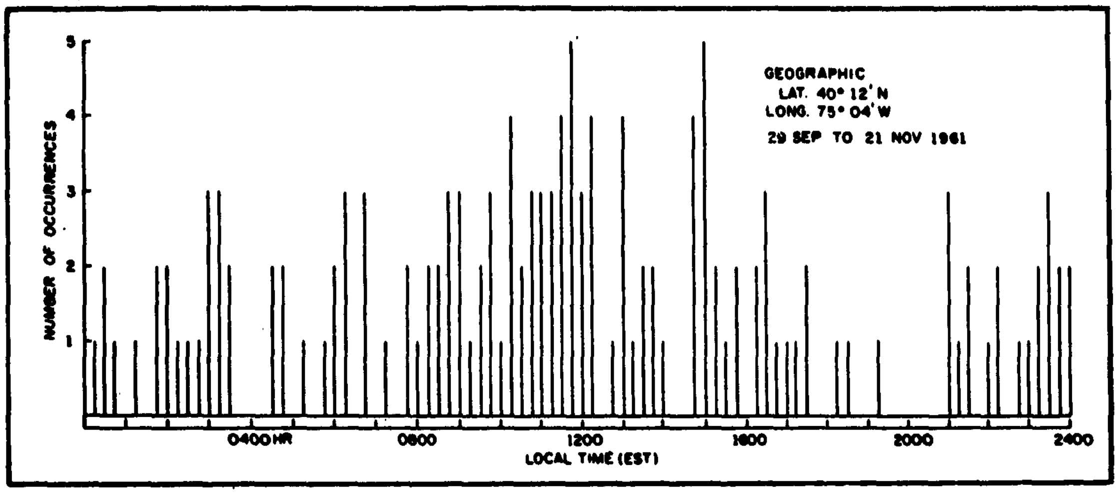

FIGURE 8 - Bar Graph Showing the Number of Occurrences of Micropulsations as a Function of Local Time for the Records Obtained Between 29 September and 21 November 1961

Figure 8 is a bar graph from the same data, showing the number of occurrences as a function of local time. The daytime peaks are evident immediately before and after 1200, and a secondary peak is evident near 2400. Quiet conditions prevail near 0400 and 2000.

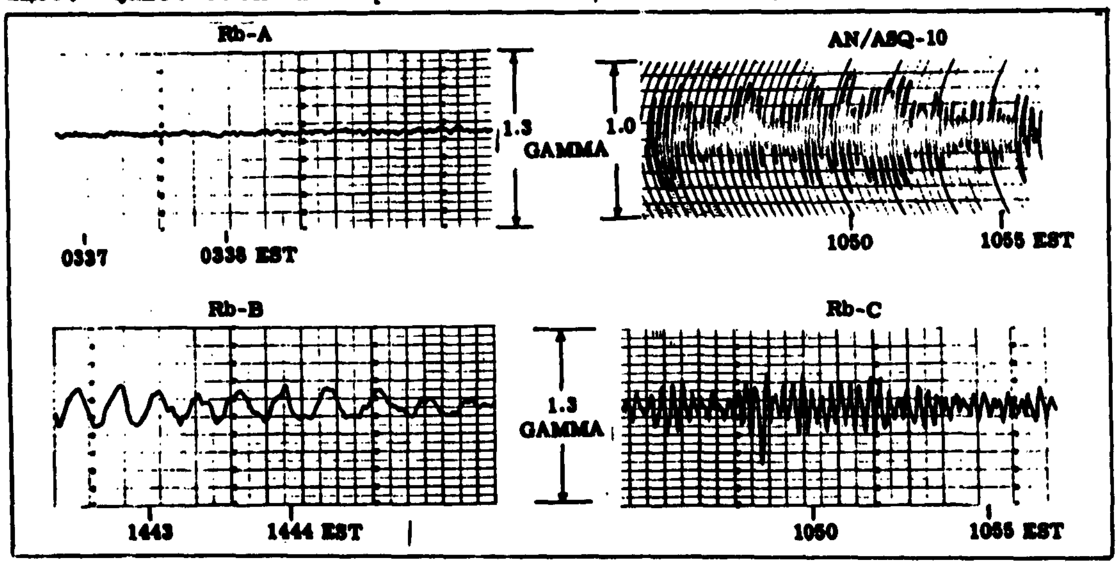

FIGURE 9 - Charts Rb-A, -B, and -C are MAD-filtered Rubidium Vapor Magnetometer Recordings, and Chart AN/ASQ-10 is an MAD Chart Obtained Simultaneously with the Rb-C Chart

Recently, a channel containing an MAD filter was added to the rubidium vapor magnetometer system. Figure 9 charts Rb-A, Rb-B, and Rb-C show recordings obtained with this filter in use. The sensitivity of the channel was approximately 1.3 gammas full scale and the chart speeds were 1 and 4 inches per minute.

Trace Rb-A, recorded during the early morning "quiet hours" on 20 October 1962 at a chart speed of 4 inches per minute, represents the minimum observable activity. On the other hand, trace Rb-B shows a high level of cyclic noise in the MAD passband as recorded at 4 inches per minute. These pulsations occurred during a phase of a magnetic storm on 19 October 1962.

Trace Rb-C was recorded at a chart speed of 1 inch per minute a little earlier in the day on 19 October. The AN/ASQ-10 record, taken at the same time, shows the correspondence between the two charts. Here again, micropulsations during a storm are producing a serious noise level that would limit the detection range of the MAD system.

ARTIFICIAL DISTURBANCE

Figure 10 shows an interesting geomagnetic disturbance that does not represent a major source of MAD interference. The trace shows the

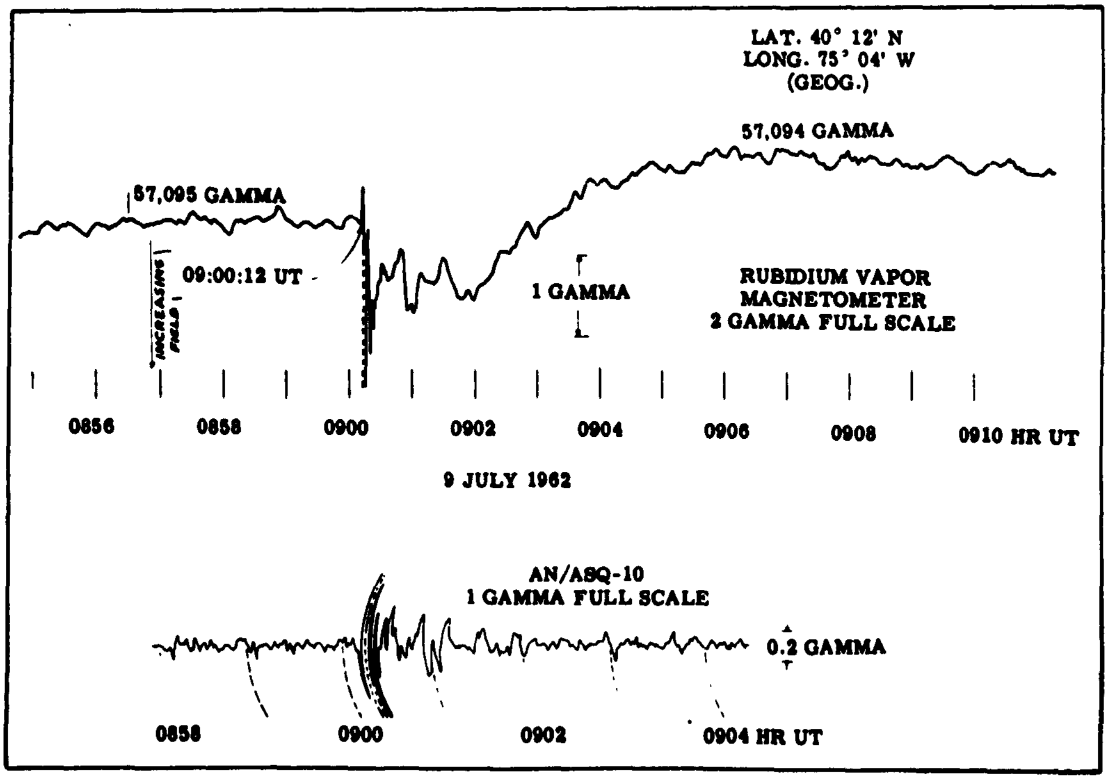

FIGURE 10 - Geomagnetic Disturbance at NAVAIRDEVCEN, 9 July 1962, at Time of High Altitude Nuclear Detonation

pulse in the geomagnetic field recorded at NAVAIRDEVCEN at 12 seconds after 0900 UT on 9 July, following the high-altitude nuclear detonation of that date. The top trace was made with the rubidium vapor magnetometer operating at a sensitivity of 2 gammas and at a chart speed of 2 inches per minute. Considerable care was taken visually to synchronize the time axis with radio time signals. The resulting time error is estimated to be less than 1 second.

The lower trace in figure 10 shows the same pulse as recorded by an AN/ASQ-10 MAD equipment operating at the same location and at a chart speed of 3 inches per minute.

As shown in both recordings, much of the first pulse was lost because of the short rise time and high intensity. However, the first and second waves are evident on both traces[6]. The rubidium vapor magnetometer trace shows that the main geomagnetic field was not disturbed for more than 5 or 6 minutes.

PLANS FOR THE PROGRAM

Plans have been made to use the MAD filter channel at the fast chart speeds for special studies when an observer is present, particularly when MAD flights are being made from NAVAIRDEVCEN. The purpose of these studies will be to obtain information on the correspondence between records taken in the aircraft over the ocean and records taken at the ground station.

The use of a dual channel recorder is also planned, so that the standard geomagnetic fluctuations can be recorded simultaneously with the output from the MAD channel, or so that the outputs from two different MAD filter channels can be compared.

An effort is also being made to keep the rubidium vapor magnetometer in continuous operation for prolonged periods, including after-hour and weekend operation. The resulting charts should provide knowledge of actual "disturbed" MAD conditions occurring during periods of several months.

6. *Berthold, W. K.; Harris, A. K.; and Hope, H. J.; "World Wide Effects of Hydromagnetic Waves Due to Argus," Journal of Geophy Research; Vol 65, No. 8; Aug 1960; pp 2233-2239*

U. S. Naval Air Development Center, Johnsville, Pa.
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II. R. P. Lepping

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